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### **(54) Responsive simultaneous frequency agile radar**

Radar mit simultan ausgesendeten Frequenzen, die veränderbar sind

Radar à émission simultanée de fréquences variables

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(56) References cited:  
**US-A- 2 877 422**                           **US-A- 3 745 578**  
**US-A- 4 123 755**

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• **F.E. TERMAN: "Radio Engineering", 3rd edition,**  
**1947, pages 496-497, chapter 9, section 9-7,**  
**McGRAW-HILL, New York, US**

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**Description****BACKGROUND OF THE INVENTION**Field of the Invention:

The present invention relates to radar and communication systems. More specifically, the present invention relates to radar and communication systems that are adapted to circumvent interference.

Description of the Related Art:

Conventional radar systems operate over a narrow band at a single carrier frequency. As a result, these systems were susceptible to interference. Many schemes have been developed to address this problem, two of which are the frequency hopping and spread spectrum schemes. Frequency hopping involves the transmission of a block of data at one carrier frequency, then "hopping" to another carrier frequency and transmitting another block of data and so on.

Unfortunately, when frequency hopping is employed, it is difficult, if not impossible, to coherently add individual pulses together to improved the signal-to-noise ratio. While slow hopping may preserve the (phase) coherency of the pulses, slow hopping is considerably more susceptible to interference.

Conventional spread spectrum systems operate at a single carrier over a wide bandwidth. However, these systems create many intermodulation products. Thus, a considerable amount of power may be wasted in spurious sidebands. In addition, the coherency of the signals is uncertain.

Further, neither the conventional frequency hopping schemes nor the conventional spread spectrum schemes fully exploit the wide bandwidth capabilities of current traveling wave tube amplifiers.

Thus, a need exists in the art for a radar transmitter which is secure from interference, offers the performance advantages of phase coherency, is power efficient and is capable of taking advantage of the broad bandwidth of current traveling wave tube amplifiers.

F.E. Terman discloses in his book "Radio Engineering" (3rd Edition, Published 1947) the use of a method and circuit often referred to as the Armstrong system. In this system, the output of a balanced modulator, consisting of two side bands with carrier suppressed, is combined with an unmodulated carrier wave which differs in phase by 90 degrees from the carrier associated with the balanced modulator. This results in a frequency-modulated wave. With this system, one is able to obtain a substantially linear relationship between the modulating voltage and phase shift up to a modulation index of approximately 0.5.

**SUMMARY OF THE INVENTION**

The need in the art is addressed by the present invention, as specified in claims 1 and 3, which provides a system for transmitting a comb of radar signals. The invention includes a phase shifter for shifting the phase of an input carrier signal. A frequency modulation signal is adjusted in amplitude by an attenuator and input to a balanced mixer. The balanced mixer mixes the input carrier signal with the attenuated frequency modulation signal. A summer combines the output of the phase shifter with the output of the balanced mixer. The system of the present invention provides an inexpensive means of generating and receiving a complex of illuminating signals having a spread spectrum consisting of lines (teeth) of carrier frequencies with controllable power. The system is agile in that the power levels and the spectral positions of the teeth may be varied.

**20 BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 is a simplified illustrative implementation of the system of the present invention.

Fig. 2a is a power spectra showing that the three frequency bands output by the system of the illustrative embodiment may be of equal power.

Fig. 2b is a power spectra showing the three frequencies generated by the present invention with more power allocated to the center frequency and correspondingly less power allocated to the two sidebands.

Fig. 3a shows a one-line power spectra.

Fig. 3b shows the three line power spectra provided by the system of the present invention.

Fig. 3c is a graph of frequency versus time showing how the frequency of a one line carrier can be varied over time.

Fig. 3d is a graph of frequency versus time showing how the frequency of the three line power spectra, of the present invention, can be varied with time.

Fig. 3e is a graph of frequency versus time showing how the frequency of the sidebands might be varied over time with respect to a center carrier frequency which has a constant frequency.

Fig. 3f is a graph of frequency versus time showing the result of sweeping the sidebands and the carrier frequency simultaneously.

Fig. 3g is a graph of frequency versus time showing the result of sweeping the sidebands only.

Fig. 3h is a graph of frequency versus time showing the result of sweeping the carrier and the upper sideband only.

**DESCRIPTION OF THE INVENTION**

Illustrative embodiments and exemplary applications will now be described with reference to the accompanying drawings.

A simplified illustrative implementation of the sys-

tem 10 of the present invention is provided in Fig. 1. The system 10 includes a 90 degree phase shifter 12, a balanced mixer 14, a first attenuator 16, a second attenuator 18 and a summer 20. An input carrier signal from an exciter (basic oscillator) or frequency reference unit (FRU) is input to the 90 degree phase shifter 12 and the balanced mixer 14. The phase shifter 12 shifts the phase of the input carrier signal and produces the center line of the output signal. The balanced mixer 14 suppresses the carrier signal and generates first and second sidebands. While two sidebands, three lines total, are probably optimum, those skilled in the art will recognize that more than two sidebands can be produced without departing from the scope of the present invention.

The balanced mixer 14 receives a frequency modulated (FM) signal through the first attenuator 16. A particularly novel aspect of the present invention is that the modulation index of the balanced mixer is controlled by the input FM signal. The modulation index of the balanced mixer 14 determines the spectral position of the sidebands produced by the balanced mixer 14. The first attenuator 16 provides coarse control of the relative amplitude of the sidebands produced by the balanced mixer. The output of the balanced mixer 14 is input to the second attenuator 18. Shown as a step attenuator, the second attenuator 18 provides fine control of the amplitude of the sidebands.

The summer combines the sidebands from the attenuator 18 with the phase shifted carrier from the phase shifter 12. The 90 degree phase shifting of the input carrier is effective to allow the sidebands to be summed with carrier without cancellation and with minimum spurious outband products. The spectral output of the summer 20 is a multiple frequency radar comb which approximates an FM signal. As shown in Fig. 1, the center line of the output signal is the phase shifted carrier and the left and right lines are the sidebands. The attenuators 16 and 18 are designed to provide sidebands of amplitudes which equal the amplitude of the center carrier. Thus, a significant feature of the present invention resides in the ability to control the allocation of available power between a number of simultaneously employed frequencies. This is illustrated in Figs. 2a and 2b. Fig. 2a shows that the three frequency bands output by the system of the illustrative embodiment may be of equal power. Fig. 2b shows the three frequencies with more power allocated to the center frequency and correspondingly less power allocated to the two sidebands.

In sum, the system 10 generates two sidebands from the carrier, phase shifts the sidebands and injects the sidebands into the carrier to provide a carrier with two sidebands instead of the single center carrier. The system 10 generates the desired frequency spectrum at low power levels. The output of the summer 20 is input to a traveling wave tube (TWT) not shown.

Fig. 3 illustrates the waveform flexibility afforded by the system of the present invention over a conventional system. With respect to power spectra, Fig. 3a shows a

one-line power spectra while Fig. 3b shows the three line power spectra provided by the system of the present invention. Fig. 3b shows that some power may be generated in spurious sidebands 22 and 24. However, judicious control of the modulation index should be effective to mitigate the production of such outbands.

With respect to carrier frequency agility, Fig. 3c shows how the frequency of a one line carrier can be varied over time, while Fig. 3d shows how the frequency of the three line power spectra, of the present invention, can be varied with time.

Fig. 3e demonstrates line separation agility by showing how the frequency of the sidebands might be varied over time with respect to a center carrier frequency which has a constant frequency.

Figs. 3f, 3g and 3h show FM modulation of the carrier frequency, variable sideband spacing and simultaneous variation of both parameters, respectively. That is, these figures show that the system of the present invention allows the sidebands and the carrier frequencies to be swept in frequency. Thus, Fig. 3f shows the result of sweeping the sidebands and the carrier frequency simultaneously. This is achieved by sweeping the input carrier frequency. Often referred to as "linear frequency modulation", Fig. 3g shows the result of sweeping the sidebands only. This is achieved by sweeping the FM signal input to the balanced mixer 14. Fig. 3h shows the result of sweeping the carrier and the upper sideband only.

Thus, the present invention provides multiple bands which may be powered, swept or hopped independently.

## Claims

1. A device (10) for transmitting a comb of radar signals, comprising:  
 a frequency source for generating an input carrier signal; means for splitting said input carrier signal into first and second portions;  
 phase shifter means (12) for shifting the phase of said first portion of said input carrier signal, to thereby produce a first output signal which comprises a phase shifted version of said input carrier signal;  
 means for generating an input frequency modulation signal;  
 balanced mixer means (14) for mixing said second portion of said input carrier signal with said input frequency modulation signal, to thereby produce a second output signal which comprises at least first and second sidebands of said input carrier signal, the spectral position of said first and second sidebands being controllable by said input frequency modulation signal;  
 first attenuator means (16) for adjusting the amplitude of said input frequency modulation sig-

<p>nal, to thereby provide a first level of control of the relative amplitude of said first and second sidebands;</p> <p>summing means (20) for combining said first output signal and said second output signal, to thereby produce a multiple frequency device output signal having a centre frequency and first and second sideband frequencies; and</p> <p>second attenuator means (18) for adjusting the amplitude of said second output signal, to thereby provide a second level of control of the relative amplitude of said first and second sidebands.</p>	5	<p>Trägersignals, um damit ein erstes Ausgangssignal zu erzeugen, welches eine phasenverschobene Version des Eingangs-Trägersignals umfaßt;</p>
<p>2. The device according to claim 1 wherein said phase shifter means (12) includes a 90 degree phase shifter.</p>	15	<p>Mittel zum Erzeugen eines Eingangs-Frequenzmodulationssignals;</p>
<p>3. A method for transmitting a comb of radar signals including the steps of:</p>	20	<p>Gegentakt-Mischstufe (14) zum Mischen des zweiten Teils des Eingangs-Trägersignals mit dem Frequenzmodulationssignal, um damit ein zweites Ausgangssignal zu erzeugen, das wenigstens erste und zweite Seitenbänder des Eingangs-Trägersignal umfaßt, wobei die spektrale Lage der ersten und zweiten Seitenbänder durch das Eingangs-Trägersignal reigbar ist;</p>
<p>splitting an input carrier signal into first and second portions;</p> <p>shifting the phase of said first portion of said input carrier signal to produce a phase shifted first output signal;</p> <p>mixing said second portion of said input carrier signal with a frequency modulation signal to produce a second output signal having first and second sidebands of said input carrier signal, the spectral position of said first and second sidebands, being controllable by said frequency modulation signal;</p> <p>attenuating the amplitude of said input frequency modulation signal to control the relative amplitude of said first and second sidebands;</p> <p>attenuating the amplitude of the second output signal; and</p> <p>combining said first and said attenuated second output signals to produce a multiple frequency device output signal having a centre carrier frequency and first and second sideband frequencies.</p>	25	<p>erstes Dämpfungsmittel (16) zum Einstellen der Amplitude des Eingangs-Frequenzmodulationssignals, um dadurch einen ersten Steuerpegel der relativen Amplitude der ersten und zweiten Seitenbänder bereit zu stellen;</p>
	30	<p>Summiermittel (20) zum Verknüpfen des ersten Ausgangssignals und des zweiten Ausgangssignals, um dadurch ein Ausgangssignal einer Mehrfrequenzvorrichtung zu erzeugen, das eine Mittenfrequenz und erste und zweite Seitenbandfrequenzen aufweist; und</p>
	35	<p>zweites Dämpfungsmittel (18) zum Einstellen der Amplitude des zweiten Ausgangssignals, um dadurch einen zweiten Steuerpegel der relativen Amplitude der ersten und zweiten Seitenbänder bereit zustellen.</p>
	40	<p>2. Vorrichtung nach Anspruch 1, bei dem das Phasenschieber-Mittel (12) einen 90°-Phasenschieber einschließt.</p>
	45	<p>3. Verfahren zum Aussenden eines Kamms bzw. Fächers von Radarsignalen, das die Schritte einschließt:</p>
	50	<p>Aufspalten eines Eingangs-Trägersignals in erste und zweite Anteile;</p>
	55	<p>Verschieben der Phase des ersten Anteils des Eingangs-Trägersignals zum Erzeugen eines phasenverschobenen ersten Ausgangssignals;</p>
	55	<p>Mischen des zweiten Anteils des Eingangs-Trägersignals mit einem Frequenzmodulationssignal zum Erzeugen eines zweiten Ausgangssignals, das erste und zweite Seitenbänder des Eingangs-Trägersignals besitzt, wobei</p>

#### Patentansprüche

1. Vorrichtung (10) zum Aussenden eines Kamms bzw. Fächers von Radarsignalen, mit:  
eine Frequenzquelle zum Erzeugen eines Eingangs-Trägersignals;  
Mittel zum Aufspalten des Eingangs-Trägersignals in erste und zweite Anteile;  
Phasenschieber-Mittel (12) zum Verschieben der Phase des ersten Anteils des Eingangs-

die spektrale Lage der ersten und zweiten Seitenbänder durch das Frequenzmodulationssignal regelbar ist;

Dämpfen der Amplitude des Eingangs-Frequenzmodulationssignals, um die relative Amplitude der ersten und zweiten Seitenbänder zu regeln;

Dämpfen der Amplitude des zweiten Ausgangssignals; und

Verknüpfen der ersten und zweiten Ausgangssignale, um ein Ausgangssignal einer Mehrfrequenzvorrichtung zu bilden, das eine Mittenträgerfrequenz und erste und zweite Seitenbandfrequenzen aufweist.

#### Revendications

1. Dispositif (10) pour émettre un peigne de signaux de radar, comprenant :

une source de fréquence pour générer un signal porteur d'entrée; 25  
 des moyens pour diviser ce signal porteur d'entrée en une première partie et une seconde partie;  
 des moyens déphasateurs (12) pour décaler la phase de la première partie du signal porteur d'entrée, pour produire ainsi un premier signal de sortie qui consiste en une version déphasée du signal porteur d'entrée; 30  
 des moyens pour générer un signal en modulation de fréquence d'entrée; 35  
 des moyens mélangeurs équilibrés (14) pour mélanger la seconde partie du signal porteur d'entrée avec le signal en modulation de fréquence d'entrée, pour produire ainsi un second signal de sortie qui comprend au moins des première et seconde bandes latérales du signal porteur d'entrée, la position spectrale de ces première et seconde bandes latérales pouvant être commandée par le signal en modulation de fréquence d'entrée; 40  
 des premiers moyens atténuateurs (16) pour régler l'amplitude du signal en modulation de fréquence d'entrée, pour procurer ainsi un premier niveau de commande de l'amplitude relative des première et seconde bandes latérales; 45  
 des moyens de sommation (20) pour combiner le premier signal de sortie et le second signal de sortie, pour produire ainsi un signal de sortie de dispositif à fréquences multiples, ayant une fréquence centrale et des première et seconde fréquences de bandes latérales; et  
 des seconds moyens atténuateurs (18) pour ré-

gler l'amplitude du second signal de sortie, pour procurer ainsi un second niveau de commande de l'amplitude relative des première et seconde bandes latérales.

5      2. Dispositif selon la revendication 1, dans lequel les moyens déphasateurs (12) comprennent un déphasateur de 90 degrés.

10     3. Procédé pour émettre un peigne de signaux de radar, comprenant les étapes suivantes :

on divise un signal porteur d'entrée en une première partie et une seconde partie;  
 on décale la phase de la première partie du signal porteur d'entrée pour produire un premier signal de sortie déphasé;  
 on mélange la seconde partie du signal porteur d'entrée avec un signal en modulation de fréquence, pour produire un second signal de sortie ayant des première et seconde bandes latérales du signal porteur d'entrée, la position spectrale des première et seconde bandes latérales pouvant être commandée par le signal en modulation de fréquence;  
 on atténue l'amplitude du signal en modulation de fréquence d'entrée, pour commander l'amplitude relative des première et seconde bandes latérales;  
 on atténue l'amplitude du second signal de sortie; et  
 on combine le premier signal de sortie et le second signal de sortie atténué, pour produire un signal de sortie de dispositif à fréquences multiples ayant une fréquence porteuse centrale et des première et seconde fréquences de bandes latérales.

FIG. 1

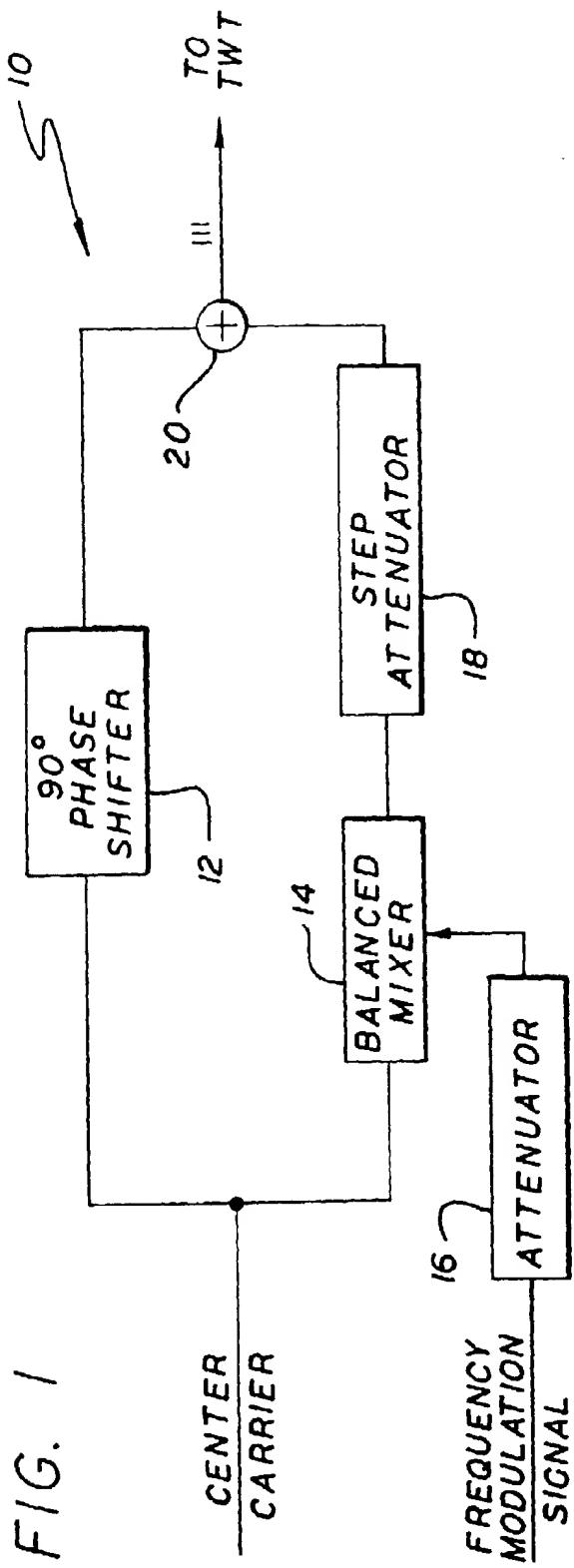


FIG. 2a

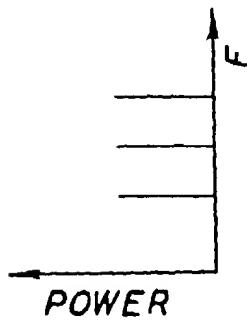


FIG. 2b

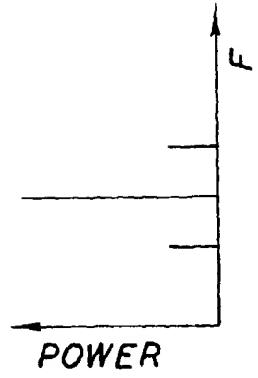
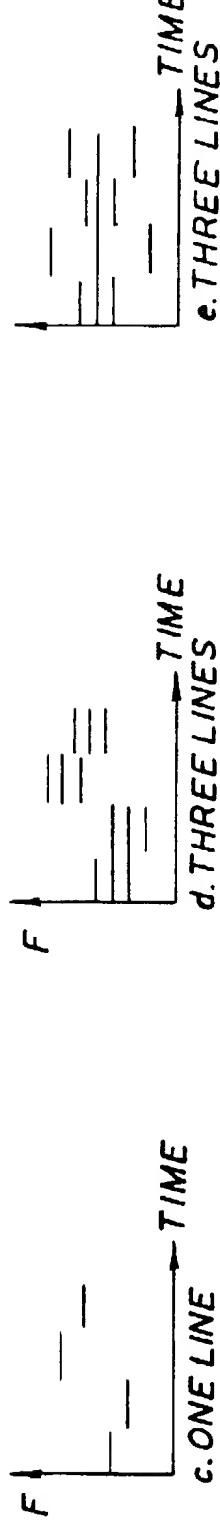


FIG. 3

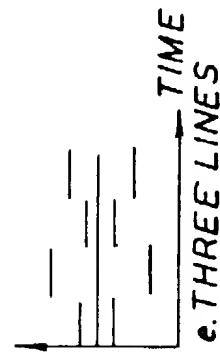
POWER SPECTRA



CARRIER FREQUENCY AGILITY



LINE SEPARATION AGILITY



LINEAR FREQUENCY MODULATION

